# Modeling Backgrounds for the Prediction of the Radar Signature of Ground Vehicles

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ABSTRACT

In this paper, we present results of modeling radar backgrounds using the program Xpatch. We created a series of backgrounds based on the parameterized Gaussian surface included with Xpatch. We compared the radar backscatter cross sections of these modeled backgrounds with the backscatter of measured backgrounds. Finally, we conclude that the backscatter cross sections of the modeled backgrounds do not match experimental data adequately enough for quantitative use.

## 1. Introduction

The radar scattering properties of backgrounds play key roles in the design of low signature ground vehicles. First, overall backscatter from the background can determine the required signature level of the vehicle. And, second, through multipath, reflections from the ground can influence the apparent signature of the vehicle.

The radar-modeling program Xpatch 2.4, an Air Force sponsored product of Demaco, includes tools for creating model backgrounds. This paper addresses the question of how to select the appropriate parameters for these tools to generate a background that simulates a real background of interest to the vehicle designer.

## 2. Background Models in Xpatch

Figure 1 illustrates a background model created in Xpatch. A simplified tank, the so-called K Tank, sits on the modeled background with bouncing rays drawn by the Xpatch ray trace visualization tool Xlook. The background is a facetized Gaussian surface characterized by a root mean square (rms) height variation and by a correlation distance in the horizontal plane.

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The background parameters used in this study are shown in Figure 2. We used three rms values and a single correlation length, all chosen to be within the range of values expected for a natural background. All the backgrounds were squares 100 inches by 100 inches divided into 1800 facets.

Definitions pertaining to scattering are illustrated in Figure 3. We used the angle of incidence, the angle between an incoming ray and the surface normal, instead of the elevation angle more common in radar work to match the practice in the experimental literature of scattering. Note also that backscatter is the dimensionless ratio of the radar cross section (RCS) of the surface and the area of the surface. In this paper, we express this ration in decibels (dB).

To predict the radar backscatter from these model backgrounds, we used Xpatch 2.4 with default Xpatchf parameters on a Silicon Graphics Indigo computer. Xpatchf calculated the RCS of the background for azimuths from 0 to 340 degrees in 18 steps of 20 degrees.

## 3. Results of Modeling Backgrounds

First, in order to select an appropriate value for rms height, we predicted the backscatter at 35 GHz for rms heights of 1, 3 and 10 inch, Figure 4. Note that each data point is an average over azimuth. Since measured backscatter for natural backgrounds are usually above 20 dB, we chose the 3 inch rms height for further study.

Figures 5, 6 and 7 plot the predicted backscatter of the 3 inch rms background at 10, 35 and 95 GHz. Note that in all cases the vertical-vertical (VV) and horizontal-horizontal (HH) values are nearly identical. Similarly the cross polarized values VH and HV are nearly equal. Also, the cross-polarized values lie 15 dB or more below the parallel polarized values.

## Experimental Data from the Literature

The literature reports backscatter measurements on a wide range of backgrounds. Figures 8 to 12 show plots based on the work of Ulaby and Haddock [1] of the University of Michigan and on the work of Peake and Oliver [2] of Ohio State University.

These figures show similar backscatter dependence on angle of incidence and on polarization. The backscatter varies only slightly with angle of incidence. Moreover, the cross polarized values are only 8 dB or so below the parallel values.

## 4. Comparison of Modeled and Experimental Backscatter Data

Figure 13 plots backscatter verses angle of incidence for both modeled and experimental backgrounds for 35 GHz and VV polarization. The plot shows the stronger dependence on angle of incidence of the modeled data.

Figure 14 further illustrates this difference. In Figure 14, the y-axis represents the backscatter at 40 degrees angle of incidence. The x-axis plots the difference between the backscatter at 20 and 60 degrees. The data point for the modeled background stands out from the natural backgrounds because of its larger dependence on angle of incidence.

## 5. Conclusions and Recommendations

We conclude that the radar backscatter from the models we studied differ significantly from the data from natural backgrounds, both in dependence on angle of incidence and in dependence on polarization. We recommend that the use of these modeled backgrounds be limited to qualitative analysis with ray tracing visualization tools.

## 6. References


1. F.T. Ulaby and T.F. Haddock, University of Michigan, 1990.

2. W/H. Peake and T.L. Oliver, Ohio State University, 1971.

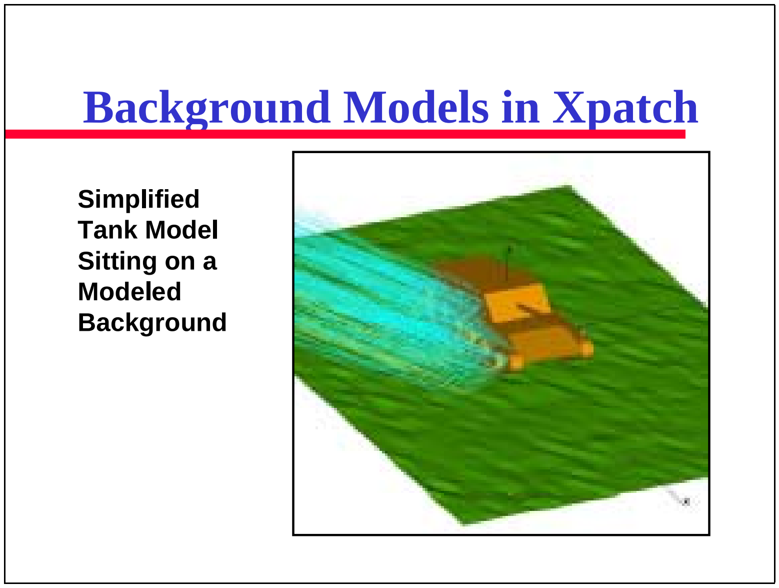


Figure 1. K Tank on a modeled background with bouncing rays.

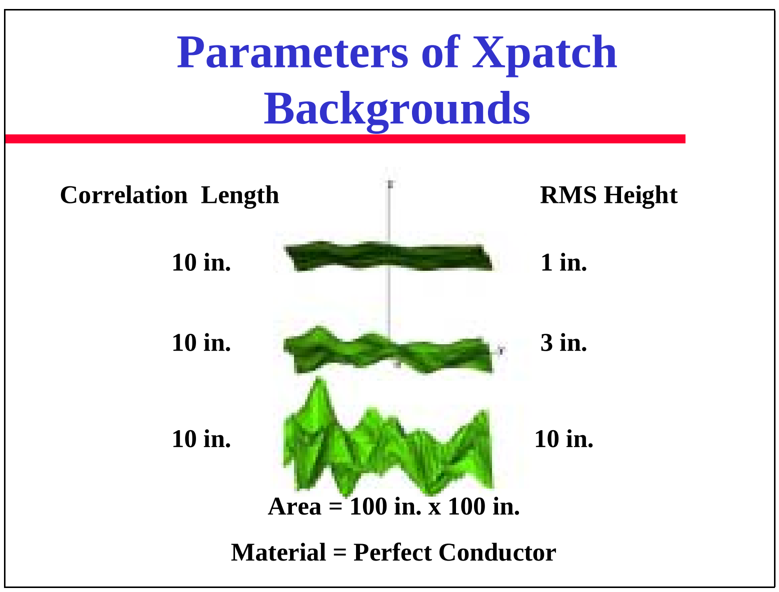


Figure 2. The parameters of the background models.

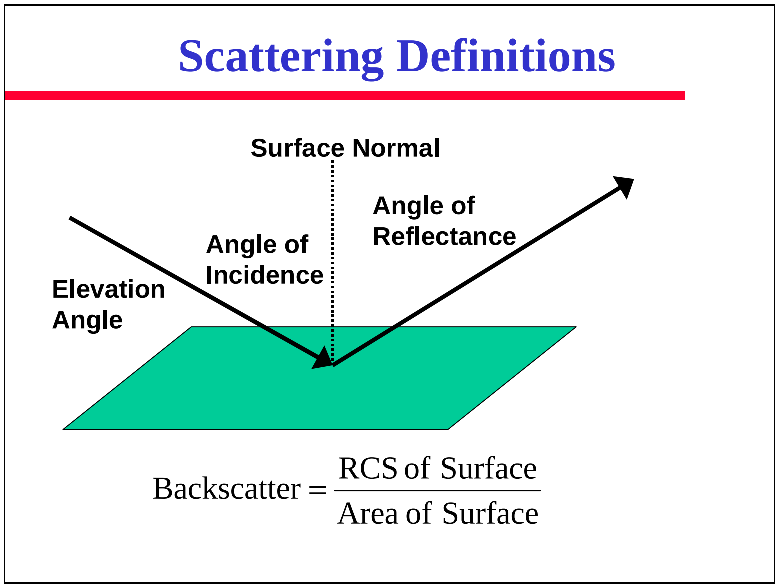


Figure 3. Scattering definitions.

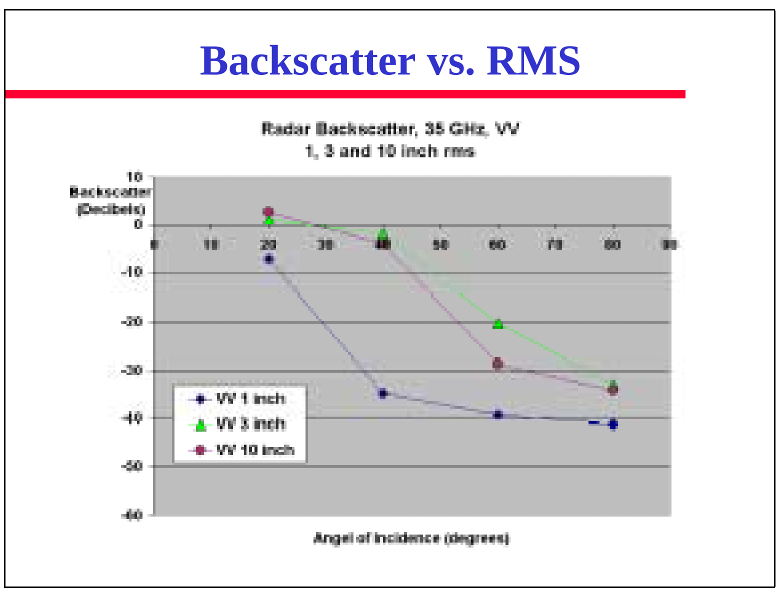


Figure 4. Backscatter for 3 values of rms height.

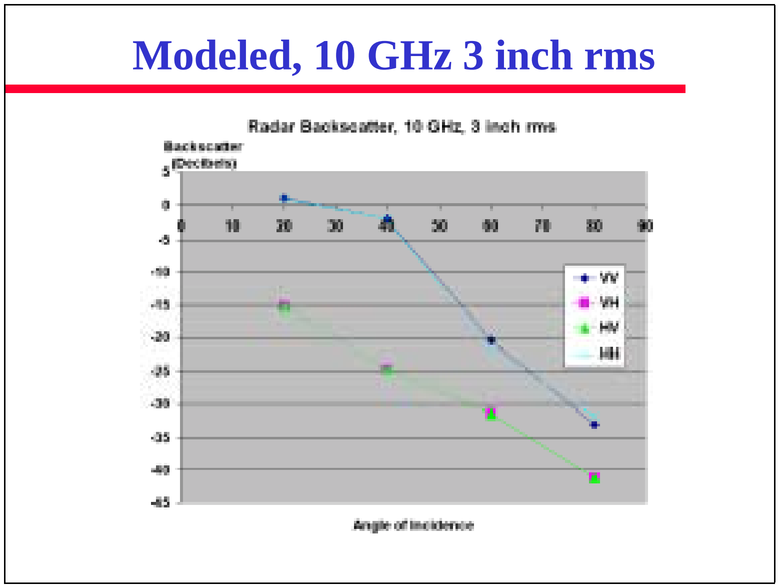


Figure 5. Modeled data at 10 GHz for 3 inch rms height.

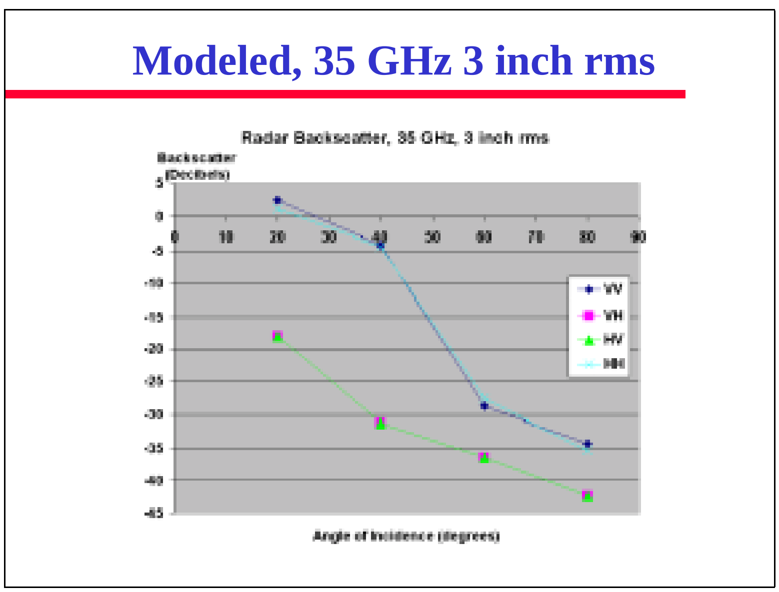


Figure 6. Modeled data at 35 GHz for 3 inch rms height.

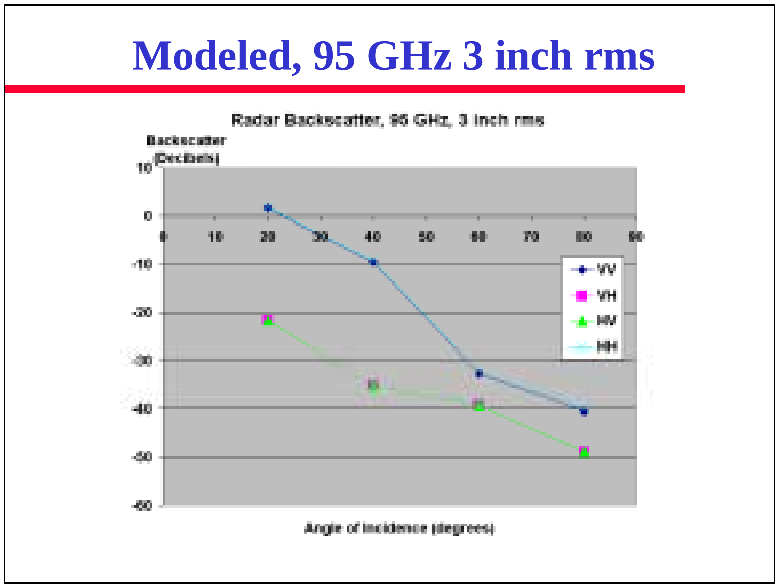


Figure 7.  Modeled data at 95 GHz for 3 inch rms height.

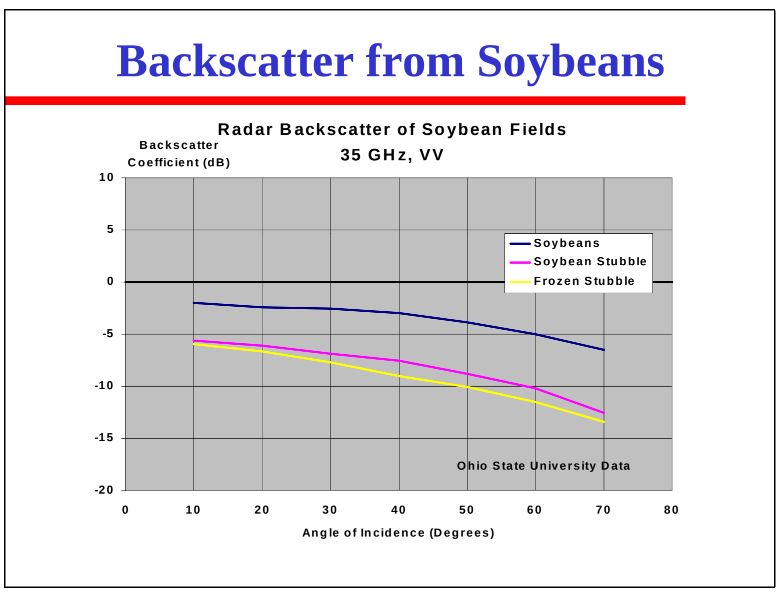


Figure 8. Backscatter from soybeans.

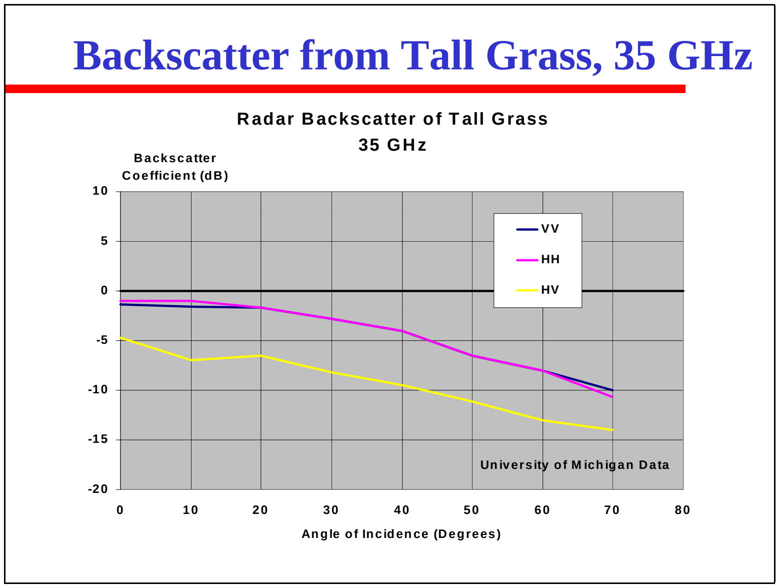


Figure 9. Backscatter from tall grass at 35 GHz.

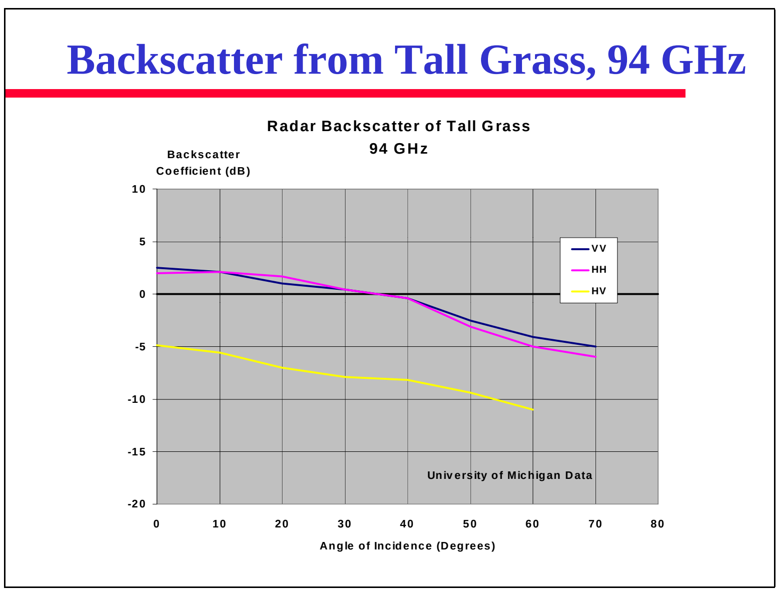


Figure 10. Backscatter from tall grass at 94 GHz.

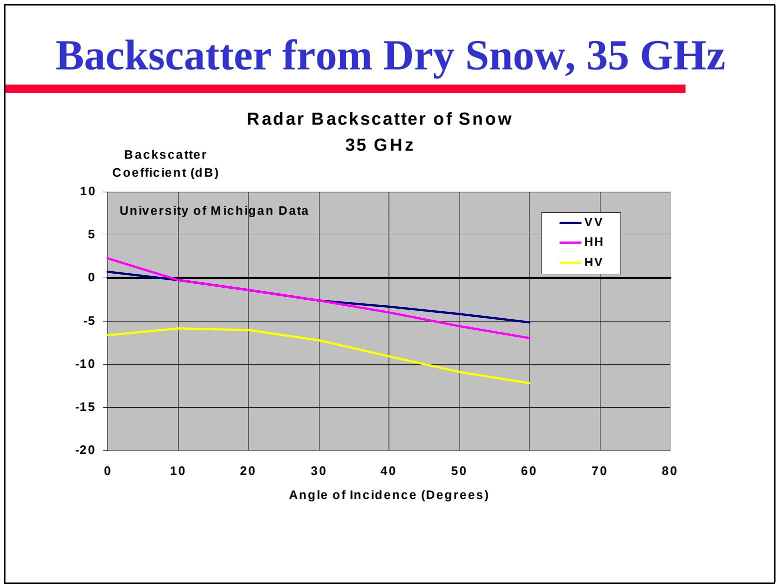


Figure 11. Backscatter from dry snow at 35 GHz.

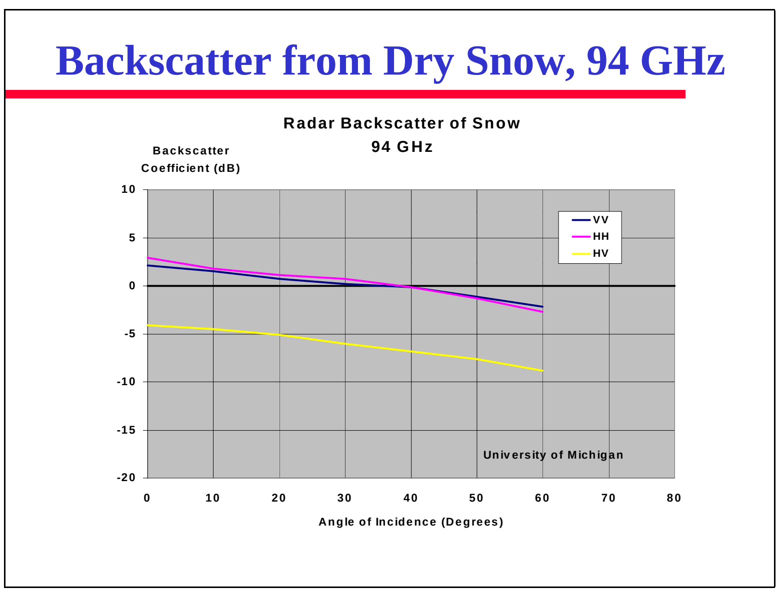


Figure 12. Backscatter from dry snow at 94 GHz.

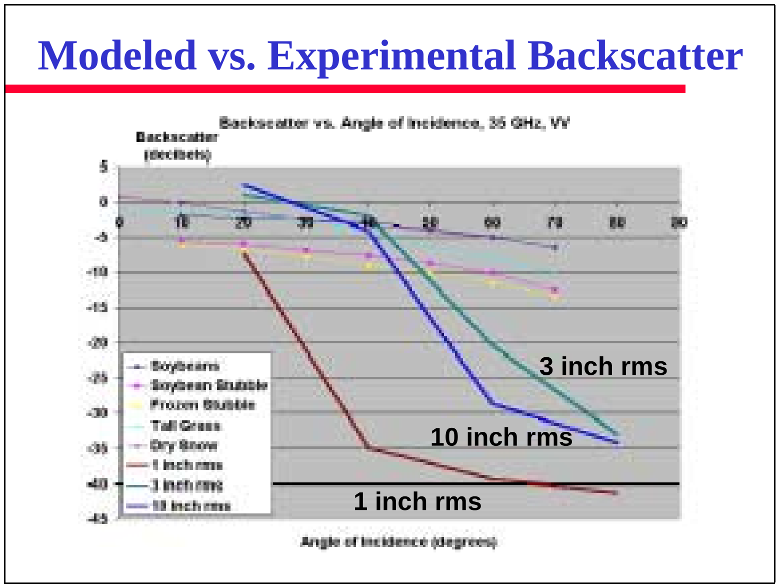


Figure 13. Comparison of modeled and experimental data.

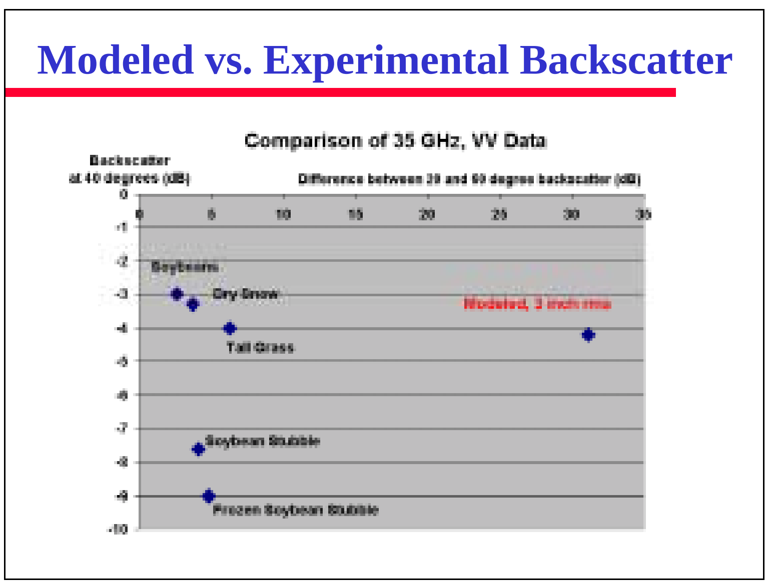


Figure 14. Comparison of modeled and experimental backscatter data.